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INTELLIGIBILITY EVALUATION OF THE TETHERED DIVER COMMUNICATIONS--ETC(U)
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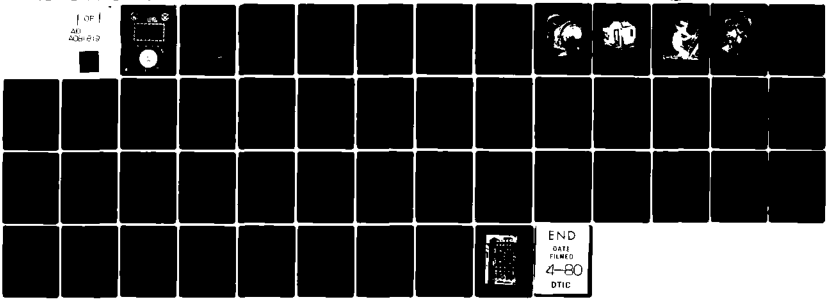

DEPARTMENT OF THE NAVY
NAVY EXPERIMENTAL DIVING UNIT
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REPORT NO. 7-79

Part I.

(6) INTELLIGIBILITY EVALUATION OF THE
TETHERED DIVER COMMUNICATIONS SYSTEM (TDCS).

Part II.

HUMAN ENGINEERING
EVALUATION OF THE TDCS.

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This Report consists of two parts:

PART I: An evaluation of the voice intelligibility of the Tethered Diver Communication System (TDCS) was undertaken during a 1000 FSW Saturation Dive conducted in the Ocean Simulation Facility (OSF) of the Navy Experimental Diving Unit (NEDU). The Griffiths (1967) version of the Modified Rhyme Test (MRT) was used as the evaluation instrument during this testing. The evaluation provided basic TDCS intelligibility data with a variety of diving rigs at a number of different depths. (CONTINUED)


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PART II; A human engineering evaluation of the TDCS was also conducted on the 1000 FSW Saturation Dive. Questionnaires were completed by most of the personnel closely involved with the day to day operation of the equipment. Recommendations were made concerning future modifications to the system.

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## ABSTRACT

### PART I

An evaluation of the voice intelligibility of the Tethered Diver Communication System (TDCS) was undertaken during a 1000 FSW Saturation Dive conducted in the Ocean Simulation Facility (OSF) of the Navy Experimental Diving Unit (NEDU). The Griffiths (1967) version of the Modified Rhyme Test (MRT) was used as the evaluation instrument during this testing. The evaluation provided basic TDCS intelligibility data with a variety of diving rigs at a number of different depths.

### PART II

A human engineering evaluation of the TDCS was also conducted on the 1000 FSW Saturation Dive. Questionnaires were completed by most of the personnel closely involved with the day to day operation of the equipment. Recommendations were made concerning future modifications to the system.

# PART I

## INTELLIGIBILITY EVALUATION OF THE TETHERED DIVER COMMUNICATIONS SYSTEM

### INTRODUCTION

#### 1.1 Scope and Background

The main objective of the Tethered Diver Communications System (TDCS) 1000 FSW saturation dive was to assess the system's operational performance with a variety of diving rigs at a variety of depths. The function of the TDCS is to enable divers to communicate with support personnel located on board ship and in an underwater personnel transfer capsule. The system has four separate communications loops which can connect as many as eight different equipment stations. The subsurface communication with the tenders and the divers is provided by FM frequency multiplexed channels over two coaxial cables. Since TDCS is to be used eventually with the wide spectrum of U.S. Navy tethered diving systems, it was tested for compatability with numerous diving rigs on this dive. The diving rigs used included the MK 11 Underwater Breathing Apparatus, the MK 14 Closed Circuit Saturation Diving System, the MK 12 Surface Supported Diving System, and the MK 1 Mod S Open-Circuit Mixed Gas Diving Rig (Figures 1 - 4).

#### 1.2 Description

As mentioned previously, TDCS is composed of four separate communication loops. The first loop, the Command Loop (Figure 5), provided one way communications from the Dive Officer Station (DO) or the Main Control Console (MCC) to Chamber B (IL), Chamber D (OL), the Trunk (TNDR), and

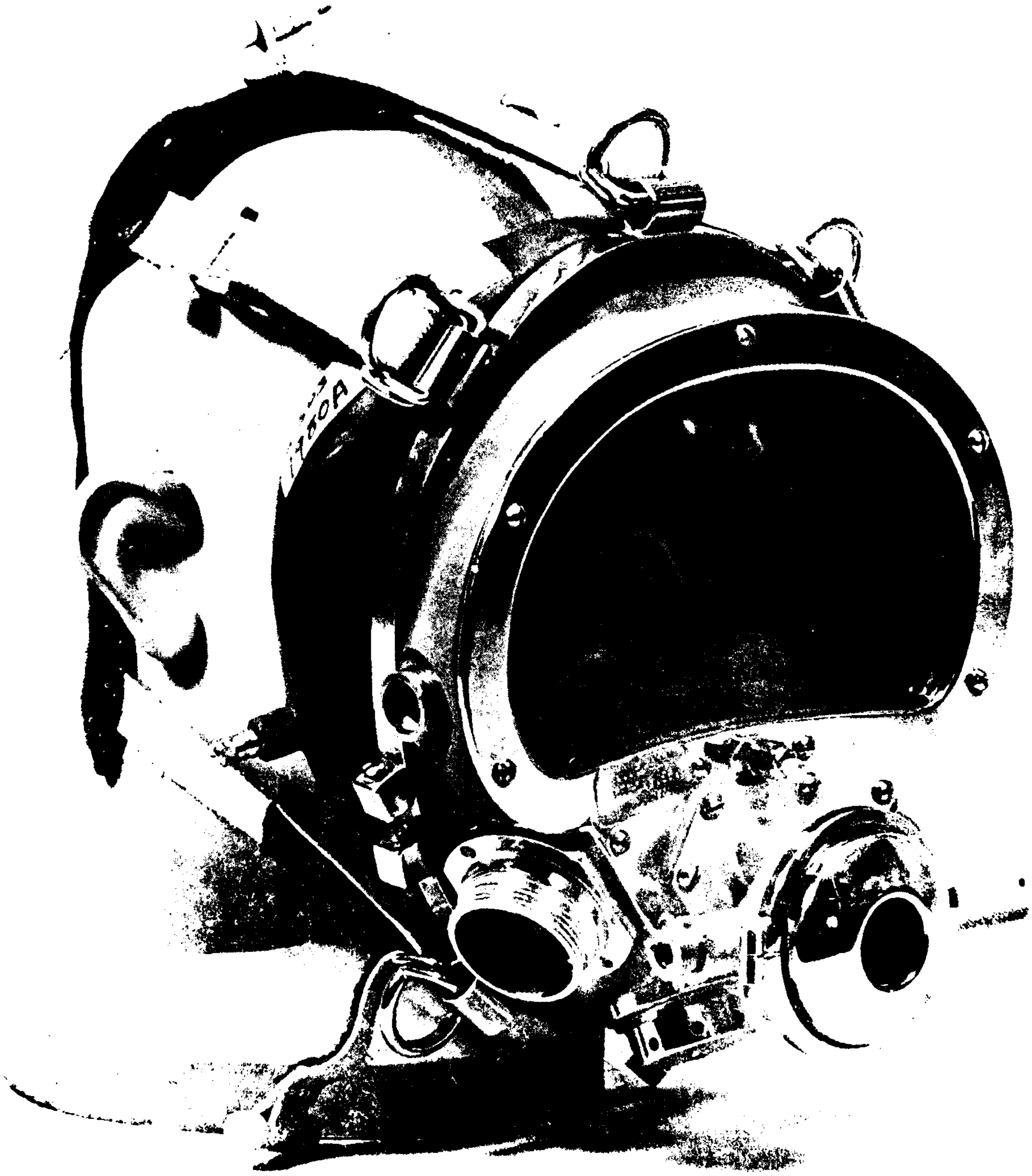


FIGURE 1. M-11 Mask

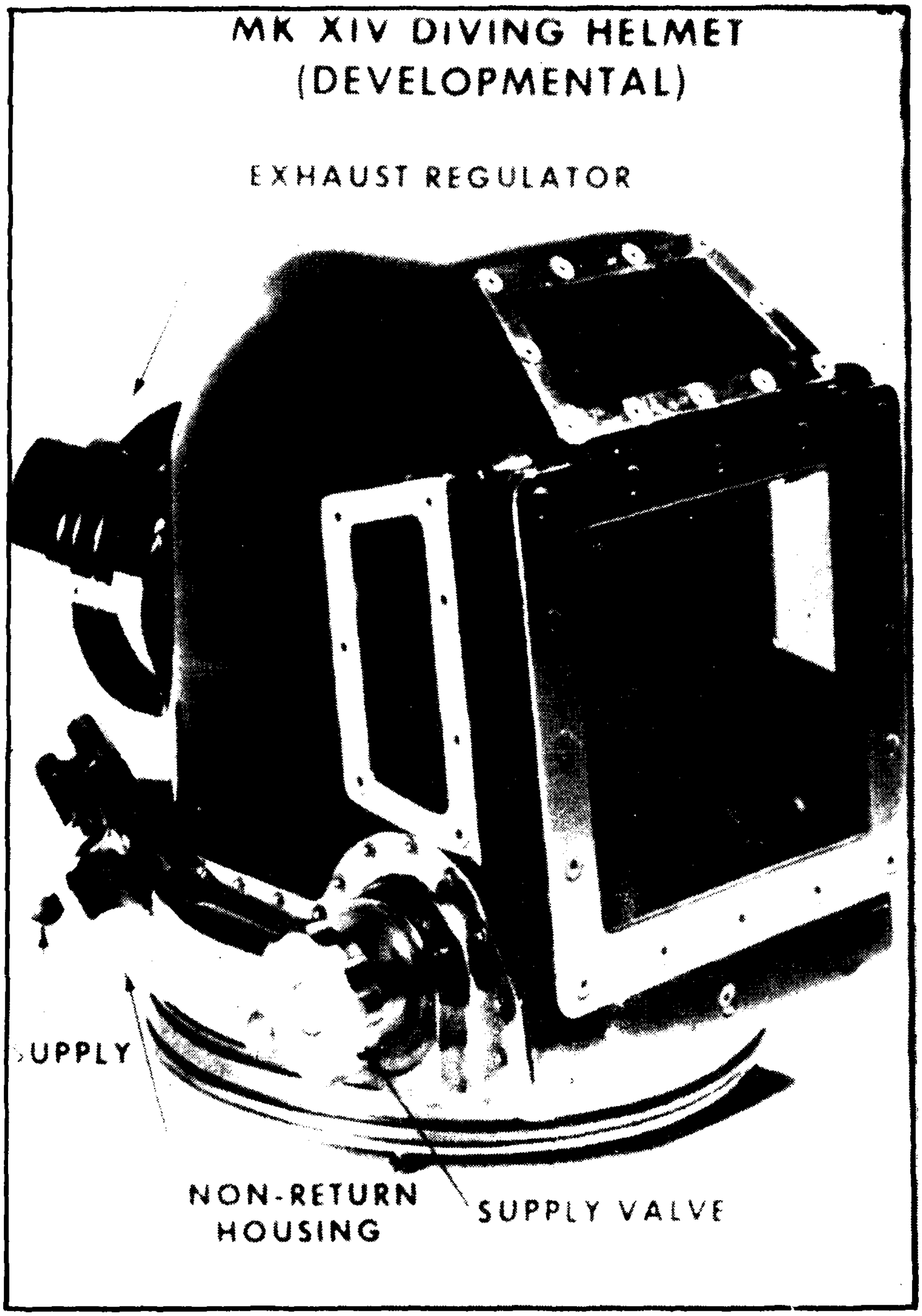



FIGURE 2. MK 14, CLOSED CIRCUIT SATURATION DIVING SYSTEM

FIGURE 3. MK 12, SURFACE SUPPORTED DIVING

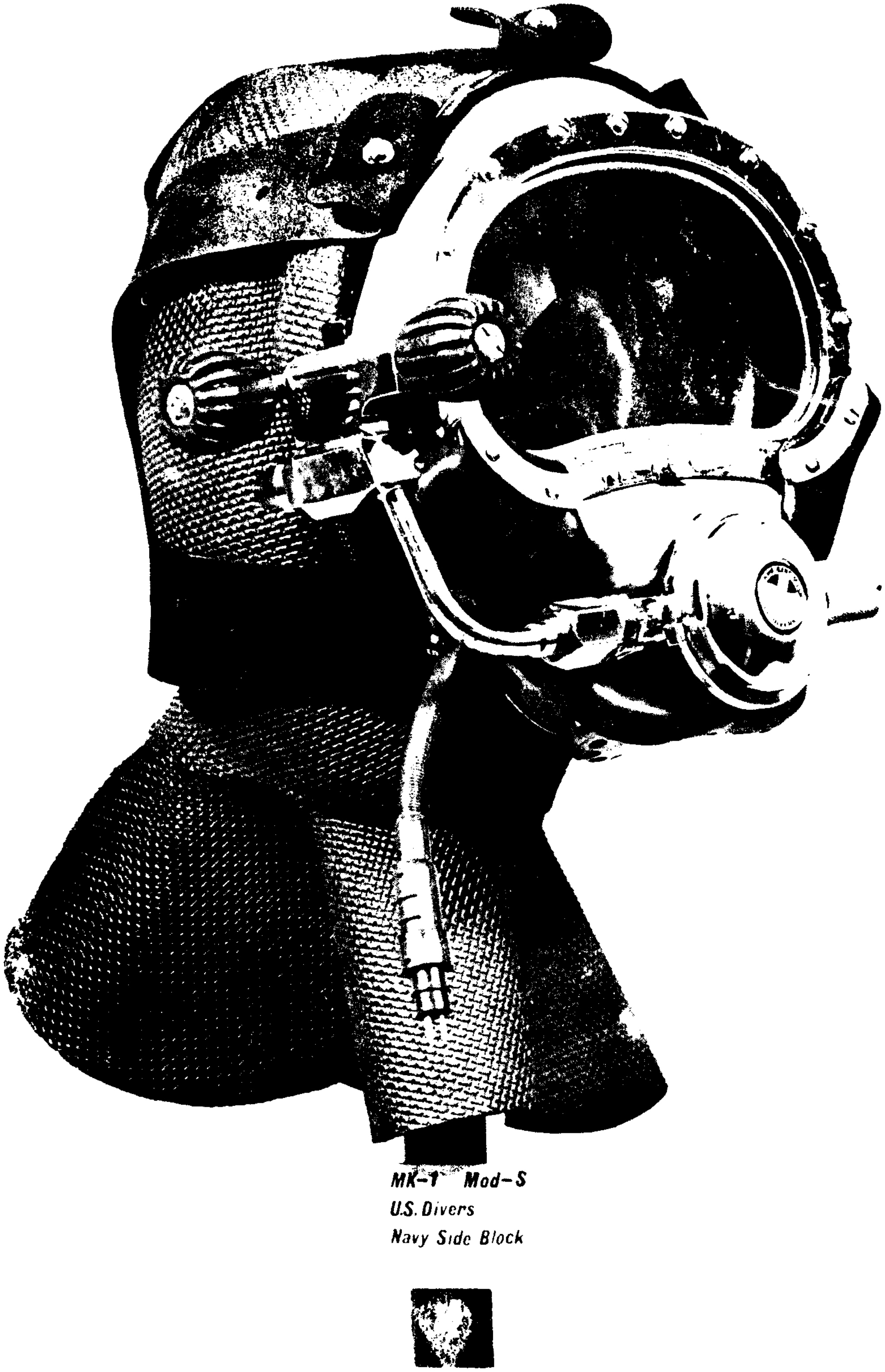
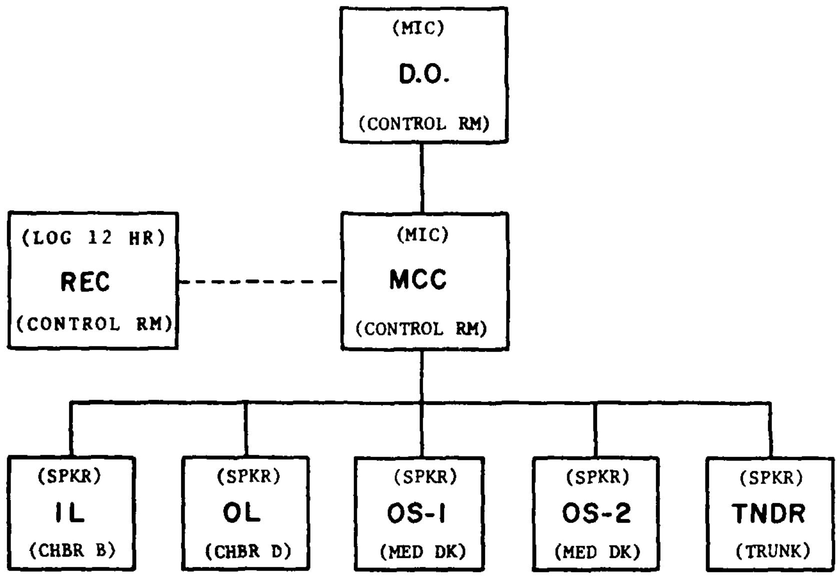



FIGURE 4. MK 1, Mod S, Open-Circuit, Mixed Gas

## COMMAND LOOP




NOTE 1. ONE WAY COMMS TO ALL STATIONS FROM D.O. AND MCC.

NOTE 2. RECORDED ON TDCS RECORDER ONLY DURING WORD LIST TESTING. RECORDED ON ONE CHANNEL OF OSF 24 HR RECORDER FOR DURATION OF DIVE.

FIGURE 5. COMMAND LOOP

the Operating Station (OS2). Command loop communications were established via push-to-talk hand microphones at the DO or MCC stations, to speakers at the IL, OL, TNDR, OS1, and OS2 stations.

The second loop, the Surveillance loop (Figure 6), provided one way communications from IL, OL, and TNDR to the DO and MCC. Surveillance Loop communications were established via open microphones at the IL, OL, and TNDR stations to a speaker at the MCC. A unique feature of the Surveillance Loop was that it incorporated a Helium Speech Unscrambler (HSU) in an effort to establish a useful surveillance capability.

The third loop, the Intercom Loop (Figure 7), provided two way communications between the DO, the MCC, IL, OL, TNDR, and the OS2. Communications were established via push-to-talk hand telephones. The MCC operator selects the proper station, and depresses the call button. Each station must depress the hand switch on the telephone unit to speak to another station. A momentary cross-connect switch was provided to allow the Diver Loop and the Intercom Loop to be inter-connected. An HSU was a component of this loop.

The final loop in the TDCS was the Diver Loop (Figure 8). This loop provided two-way communications between the DO, the MCC, the Trunk (TNDR 1 & 2), the Divers (DV 1, 2, 3, & 4), and the OS1. Two Helium Speech Unscramblers (HSU 1 & 2), allowing separate control of individual divers voices or divers and tenders voices, were employed in this loop. In the case of an emergency (failure of either unit) it was possible to cross-connect the HSU units.

## SURVEILLANCE LOOP

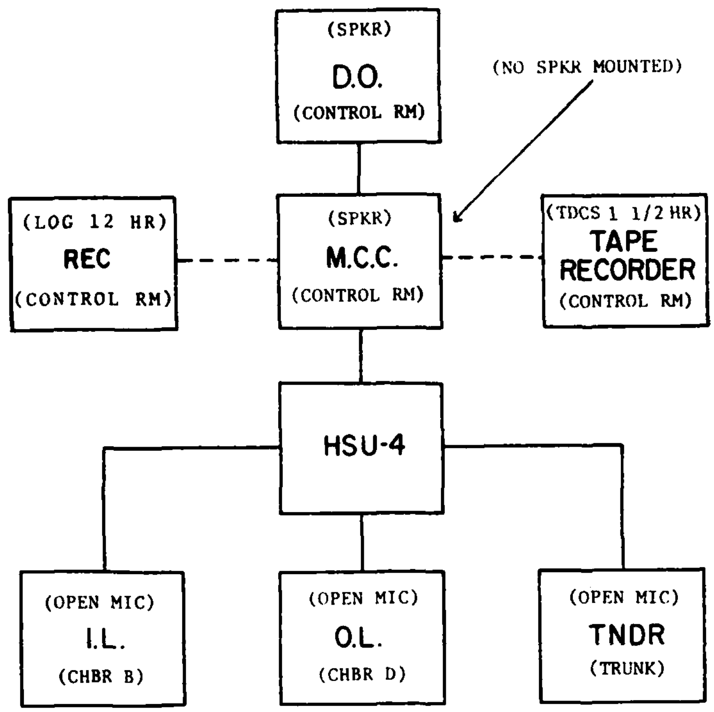



FIGURE 6. SURVEILLANCE LOOP

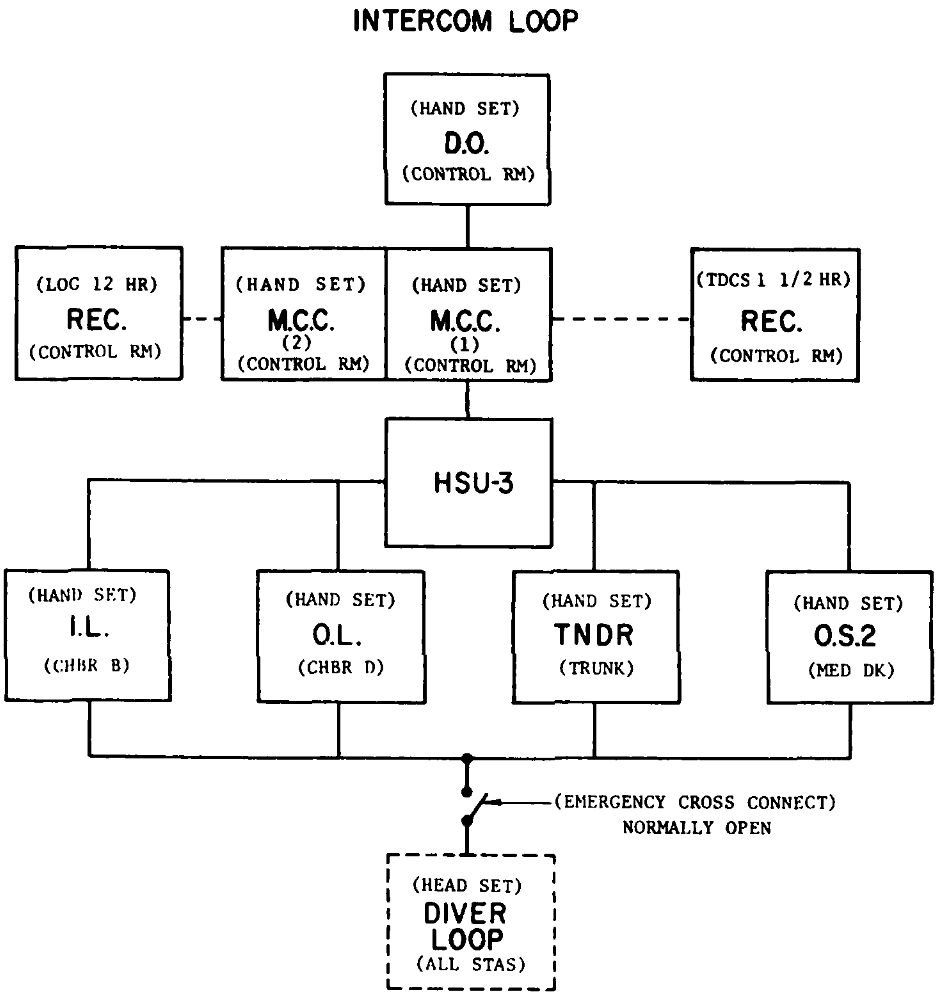



FIGURE 7. INTERCOM LOOP

DIVER LOOP

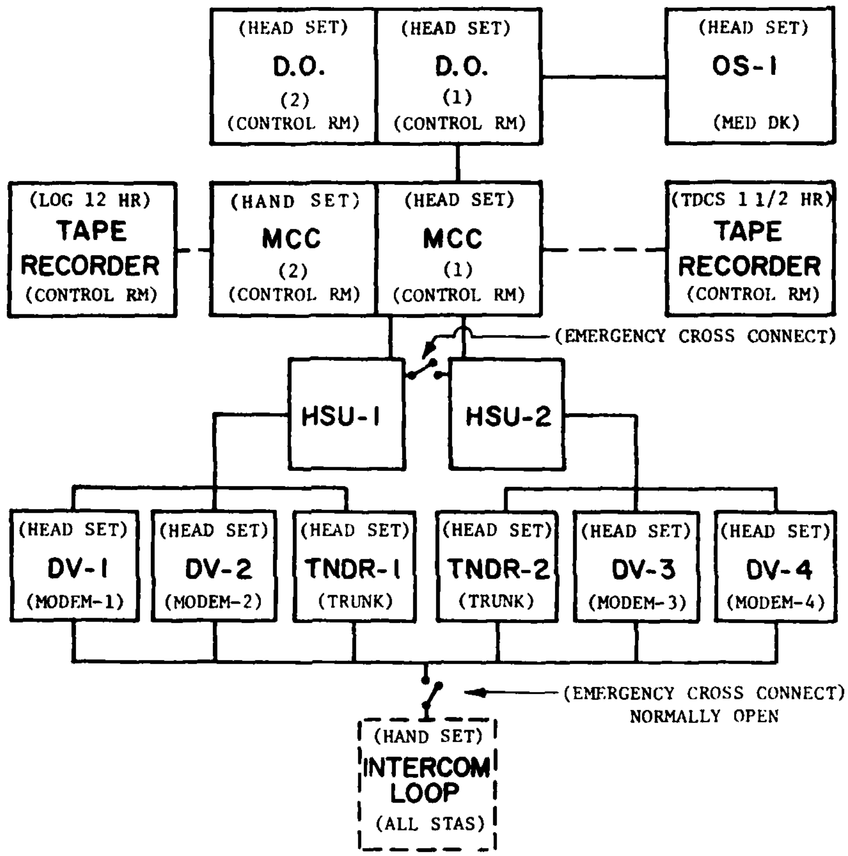



FIGURE 8. DIVER LOOP

# SECTION 2

# METHOD

## 2.1 Subjects

Six male subjects, ranging in age from 28 to 37 years, were employed in this study. All were First Class and/or Saturation qualified divers and were experienced in the use of each of the diving systems the TDCS encompassed. Prior to the dive, each diver was subjected to a complete physical examination. An audiometric examination showed all subjects to have hearing within normal limits.

## 2.2 Test Materials and Apparatus

Because intelligibility is the ultimate index of the effectiveness of any voice communication system, an objective means of assessing the intelligibility of TDCS was required. The Griffiths (1967) version of the previously developed Modified Rhyme Test (House, et al, 1965) was employed for this purpose. It was chosen because of its ease of administration and scoring, its stability with respect to learning effects, and because it requires minimal listener training. Gelfand, et al, 1978, report the successful use of the test on a 1600 FSW dive. Although the Modified Rhyme Test (MRT) is not phonetically balanced to represent everyday speech, it is efficient and useful because it requires perception of consonantal sounds, sounds that are difficult to transmit successfully and are thus more important than vowels to intelligibility.

The MRT consists of words, with five words in each set. In a typical test, a reader reads one specific word from each set in the following way: "Number 1, the word is_____, Number 2, the word is_____," etc. He was instructed to pause several seconds between each phrase.

The listener who held a response sheet with the same 50 sets of words, marked the correct word read from each set by the reader. Eight different reading lists were randomly employed during the course of the evaluation and six different response lists. The order of the words within each set on the various response word lists were different to counterbalance the tendency of listeners to mark the first word in a set when in doubt or when guessing. Once a word list was completed, the percent correct was calculated using the following formula (Van Cott & Kincaid, 1972):

$$\% \text{ correct} = \left(\text{No. Right} - \frac{\text{No. Wrong}}{4}\right) \times 2$$

The number of wrong answers was divided by four and subtracted from the number of right answers. The resultant was then multiplied by two. This manipulation was essentially a correction factor for guessing.

Reading and response word lists were printed on a synthetic paper (Kimdura), manufactured by Kimberly Clark Corp., Neenah, WI. Unlike laminated word lists which are highly susceptible to helium intrusion during deep dives, Kimdura does not readily embolize when brought to the surface from deep depths.

All MRT readings from depth were recorded topside on a SONY TC-388-4 three-head four-channel reel to reel tape recorder. The response characteristics of this recorder are shown in Figure 9.

## 2.3 Procedure

Prior to the actual dive, all dive subjects practiced and familiarized themselves with the word list test procedure for approximately one week. This involved day to day simulation of the actual procedures to be used at depth.

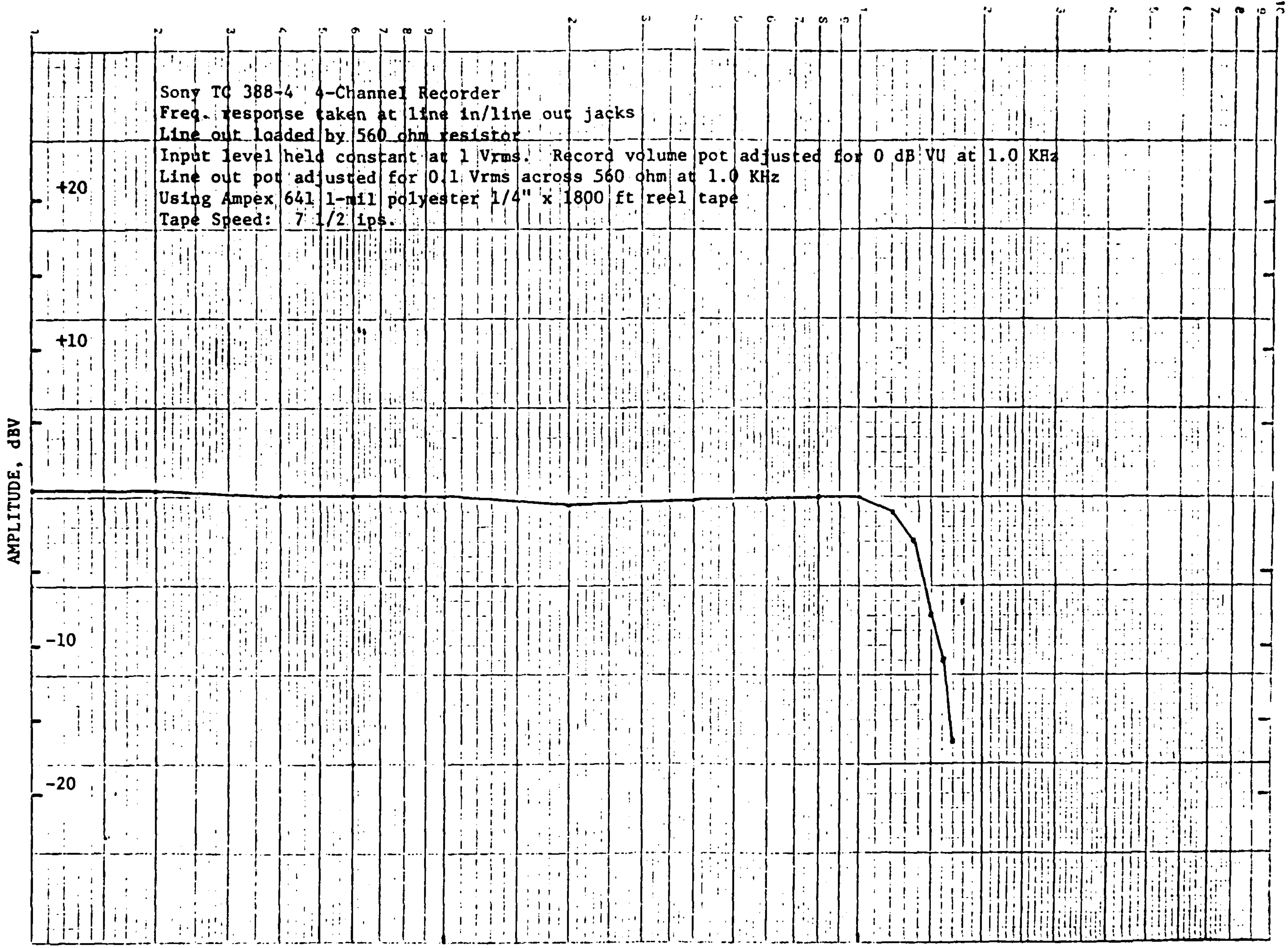

Sony TC 388-4 4-Channel Recorder
Freq. response taken at line in/line out jacks
Line out loaded by 560 ohm resistor
Input level held constant at 1 Vrms. Record volume pot adjusted for 0 dB VU at 1.0 KHz
Line out pot adjusted for 0.1 Vrms across 560 ohm at 1.0 KHz
Using Ampex 641 1-mil polyester 1/4" x 1800 ft reel tape
Tape Speed: 7 1/2 ips.
+20
+10
-10
-20
AMPLITUDE, dBV
1K
10K
FREQUENCY

FIGURE 9.

Intelligibility data on TDCS was collected at several depths during the course of the dive: 450 FSW, 1000 FSW, and at a variety of intermediate depths during decompression. In a typical dive, data on diver to diver communications, diver to PTC, PTC to diver, PTC tender $_1$ to PTC tender $_2$, MCC to diver, MCC to PTC, diver to MCC, and PTC to MCC were obtained utilizing the Diver Loop of TDCS. On the Intercom Loop, OL to PTC communications and MCC to PTC data was collected. On Command Loop, MCC to OL and MCC to PTC data was obtained. And lastly, on Surveillance Loop, PTC to MCC and OL to MCC intelligibility data was collected.

At 450 FSW (Dive Day 2-4), it was originally planned to test the TDCS Diver Loop with three diving rigs, MK 11, MK 1, and MK 14 and to test the remaining TDCS communication loops. Valid intelligibility data on the Diver Loop was only obtained on the MK 11 diving rig due to communication problems encountered when using TDCS with the MK 1 and MK 14. The details of these difficulties are discussed later in this paper.

At 1000 FSW (Dive Days 15-17), MK 11, MK 1, and MK 14 were again scheduled to be tested in various combinations on the Diver Loop. Also, Intercom, Command, and Surveillance Loops were to be evaluated. Valid intelligibility data on the Diver Loop was obtained only for MK 11 and MK 1 rigs due to continuing MK 14 communication difficulties.

Diver Loop testing was conducted throughout saturation decompression beginning on Dive Day 19 (720 FSW) and concluding on Dive Day 25 (146 FSW). During this lengthy period, the MK 12 was tested with TDCS as well as the previously mentioned diving rigs.

# SECTION 3

# RESULTS

Diver Loop mean intelligibility scores for two MK 11 divers in the water at 450 FSW is presented in Table 1. Each mean score was based on no less than six data points (a minimum of 300 words). The lowest intelligibility scores occurred when a MK 11 diver was talking, ie. MK 11 diver to MK 11 diver, MK 11 diver to PTC, and MK 11 diver to MCC. There are several possible explanations for this depressed intelligibility. First, the hydroseal of the M-11 mask may be affecting speech articulation because of its pressure on facial and jaw muscles. And second, oral/nasal acoustics in the M-11 mask may be interacting with the TDCS microphone creating a less than optimal signal. Intelligibility scores in 70-75% range on the MRT are generally considered "not acceptable for operational equipment". Table 2 shows the intelligibility criteria for voice communications systems (Mil-Std-1472B). As can be seen, the center column represents the MRT percent intelligibility criteria. The first column, PB, and last column, AI, refer to two alternative intelligibility assessment tests - the Phonetically Balanced Word List and the Articulation Index, respectively. Except for those instances when the MK 11 diver was the talker, all other configurations demonstrated acceptable levels of voice intelligibility according to this criteria. It is important, however, to realize that Mil-Std-1472B criteria are based on the original MRT (House, et al., 1965) not the modified Griffiths version employed in the study, and that the criteria was not intended to account for losses in auditory sensitivity that occur in hyperbaric environments (see Adolfson and Berghage, 1974). With this in mind then, the 70-75% scores obtained when the MK 11 diver talked cannot be immediately taken as unacceptable when assessing the TDCS system per se. The two, however, do not differ to such a degree that the criteria cannot be used in a general manner to assess TDCS intelligibility.

TABLE 1.

Mean Intelligibility Scores For Two MK 11 Divers

In The Water at 450 FSW (Diver Loop).

| Talker/Listener | % Correct |
|---|---|
| MK 11 Diver to MK 11 Diver | 75 (SD = 11) |
| MK 11 Diver to PTC | 70 (SD = 12) |
| PTC to MK 11 Diver | 83 (SD = 8) |
| MCC to MK 11 Diver | 95 (SD = 4) |
| MK 11 Diver to MCC | 70 (SD = 8) |
| MCC to PTC | 90 (SD = 7) |
| PTC to MCC | 88 (SD = 6) |
| PTC Tender 1 to PTC Tender 2 | 82 (SD = 5) |

TABLE 2 INTELLIGIBILITY CRITERIA FOR VOICF COMMUNICATIONS SYSTEMS (MIL-STD-1472B, 31 December 1974)

| COMMUNICATION REQUIREMENT | SCORE | | |
| --- | --- | --- | --- |
| | PB | MRT | AI |
| Exceptionally high intelligibility; separate syllables understood | 90% | 97% | 0.7 |
| Normally acceptable intelligibility; about 98% of sentences correctly heard; single digits understood | 75% | 91% | 0.5 |
| Minimally acceptable intelligibility; limited standardized phrases understood; about 90% sentences correctly heard (not acceptable for operational equipment) | 43% | 75% | 0.3 |

Testing of two MK 1 divers, and a MK 11 and a MK 1 diver were not accomplished at 450 FSW. The TDCS mike in these configurations appeared to be very sensitive to normal changes in the amplitude of the diver's voices, and gas flows in the open-circuit MK 1 resulted in INAC (Inhalation Noise Attenuation Circuit) activation difficulties. In addition, the TDCS microphone tended to overdrive the HSU in the high frequency range.

Attempts to obtain intelligibility data on the MK 14 was also unsuccessful due to gas flow/microphone interaction in the hat and feedback problems associated with the helmet-mounted speakers and exposed TDCS microphone.

The remaining communication loops were tested at 450 FSW and mean intelligibility scores are presented in Table 3. Both Intercom and Command Loop intelligibility are of an acceptable level. The lowest intelligibility on the Intercom Loop was between the OL and PTC (78%). In this configuration, both talker and listener are at depth.

The Surveillance Loop, a monitoring loop not generally used for primary communication, had intelligibility scores (Table 3) well below minimally acceptable levels. It should be recognized, however, that other existing monitoring loops do not employ an HSU and thus demonstrate virtually no intelligibility. Given that this system utilizes an open mike within the hyperbaric chambers exposed continually to the substantial noise of the life-support blowers and that the divers sat across the chamber facing the mike when speaking, the level of intelligibility obtained was remarkable.

TABLE 3.

Mean Intelligibility Scores For Intercom,

Command, and Surveillance Loops at 450 FSW.

| Talker/Listener | % Correct |
|---|---|
| Intercom Loop | |
| OL to PTC | 78 (SD = 8) |
| MCC to OL | 96 (SD = 4) |
| OL to MCC | 87 (SD = 5) |
| MCC to PTC | 94 (SD = 3) |
| Command Loop | |
| MCC to OL | 95 (SD = 4) |
| MCC to PTC | 95 (SD = 2) |
| Surveillance Loop | |
| PTC to MCC | 66* (SD = 9) |
| OL to MCC | 41* (SD = 10) |

*Scores well below the Mil-Std-1472B criteria.

At a depth of 1000 FSW, Diver Loop intelligibility scores dropped uniformly across talker/listener configurations. Mean intelligibility data is shown in Table 4 for two MK 11 divers in the water at 1000 FSW. Note that four of the configurations have intelligibility scores well below minimally acceptable levels (Mil-Std-1472B) and that all of these configurations have both the talker and listener at depth. Since a listener at depth heard processed speech, intelligibility was a function of both the quality of the HSU and his own auditory sensitivity at this considerably deeper depth. How each may be contributing to this loss in intelligibility is not known. Interacting with these two variables is the change in the diver's voice and concomitant change in the appropriate HSU settings which may also be altering measured intelligibility. A further indication of a TDCS headphone alteration at depth, or an actual auditory sensitivity change in the divers is the lowering of intelligibility found when the MCC talked to the MK 11 diver or PTC. This speech was of course "unprocessed" since it originated on the surface and one would expect that depth of the divers would have had no effect on its intelligibility. However, a comparison with the data obtained at 450 FSW suggests that in fact some change had occurred.

The results of the evaluation of two MK 1 divers in the water at 1000 FSW is shown in Table 5. The only acceptable level of intelligibility was MCC to MK 1 diver and MCC to PTC. As can be seen, all other configurations fell well below minimally acceptable intelligibility levels. It is felt that the MK 1 gas flow noise and the INAC component of TDCS interacted in such a way as to produce broken and near-garbled speech intermittently throughout this testing. In an effort to determine if INAC onset time was affecting speech clarity, a "split half" evaluation of the MRT was conducted on dives in which

TABLE 4

Mean Intelligibility Scores For Two MK 11 Divers in The Water

At 450 FSW (Diver Loop)

| Talker/Listener | % Correct |
|---|---|
| MK 11 Diver to MK 11 Diver | 67* (SD = 12) |
| MK 11 Diver to PTC | 64* (SD = 9) |
| PTC to MK 11 Diver | 67* (SD = 12) |
| MCC to MK 11 Diver | 86 (SD = 7) |
| MK 11 Diver to MCC | 75 (SD = 9) |
| MCC to PTC | 85 (SD = 9) |
| PTC to MCC | 79 (SD = 8) |
| PTC Tender 1 to PTC Tender 2 | 67* (SD = 14) |

*Scores well below the Mil-Std-1472B criteria.

TABLE 5

Mean Intelligibility Scores for Two MK 1 Divers

In The Water at 1000 FSW (Diver Loop).

| Talker/Listener | % Correct |
|---|---|
| MK 1 Diver to MK 1 Diver | 50* (SD = 8) |
| MK 1 Diver to PTC | 47* (SD = 16) |
| PTC to MK 1 Diver | 54* (SD = 16) |
| MCC to MK 1 Diver | 80 (SD = 12) |
| MK 1 Diver to MCC | 66* (SD = 13) |
| MCC to PTC | 82 (SD = 10) |
| PTC to MCC | 65* (SD = 10) |
| PTC Tender 1 to PTC Tender 2 | 53* (SD = 14) |

*Scores well below the Mil-Std-1472B criteria.

INAC was used. This simply means that percent correct was computed for the first half of the MRT word list, where the trailing consonants in each word were changing, and for the last half of the MRT, where the leading consonants of the words are changing, to determine if significant differences exist. If a difference was evident, then it would suggest that INAC was "clipping" a portion of the words spoken. The split-half analysis conducted on this data showed no significanct differences, however. Thus, INAC onset time does not appear to be implicated.

Table 6 contains the data for a MK 11 diver and a MK 1 diver in the water at 1000 FSW. In this configuration, adequate communication was exhibited from MK 1 diver to MCC, PTC to MCC, and from MCC to MK 11 diver, MK 1 diver, and PTC. It is interesting to note that these configurations had either a talker or a listener on the surface (not under pressure) and that those configurations involving two stations at depth (for instance, diver to diver, or PTC to diver) had generally unacceptable intelligibility levels. One way of explaining the low intelligibility between PTC tender 1 and 2 independent of the diving rigs being used, was the fact that each tender had one ear exposed to the ambient noise in the chamber while the other was covered by the earphone. So, when speaking to each other they simultaneously hear the raw helium speech with the exposed ear and processed TDCS speech with the other. Such an arrangement is not condusive to maximum communication efficiency.

The last configuration on the diver loop successfully tested at 1000 FSW was two MK 11 divers and a MK 1 diver in the water simultaneously. The results of this evaluation are shown in Table 7. As can be seen, the obtained data are

TABLE 6

Mean Intelligibility Scores of a MK 11 Diver and MK 1 Diver

In The Water at 1000 FSW (Diver Loop).

| Talker/Listener | % Correct |
|---|---|
| MK 11 Diver to MK 1 Diver | 59* (SD = 12) |
| MK 1 Diver to MK 11 Diver | 67* (SD = 16) |
| PTC to MK 11 Diver | 64* (SD = 11) |
| PTC to MK 1 Diver | 59* (SD = 10) |
| MK 11 Diver to PTC | 61* |
| MK 1 Diver to PTC | 65* (SD = 13) |
| MK 11 Diver to MCC | 53* (SD = 16) |
| MK 1 Diver to MCC | 70 (SD = 16) |
| MCC to MK 11 Diver | 81 (SD = 8) |
| MCC to MK 1 Diver | 87 (SD = 4) |
| PTC to MCC | 71 (SD = 8) |
| MCC to PTC | 88 (SD = 6) |
| PTC Tender 1 to PTC Tender 2 | 66* (SD = 10) |

*Scores well below the Mil-Std-1472B criteria.

TABLE 7

Mean Intelligibility Scores of Two MK 11 Divers and a MK 1 Diver

In The Water at 1000 FSW (Diver Loop)

| Talker/Listener | % Correct |
|---|---|
| MK 11 Diver to MK 11 Diver | 58* (SD = 12) |
| MK 11 Diver to MK 1 Diver | 60* (SD = 13) |
| MK 1 Diver to MK 11 Diver | 53* (SD = 17) |
| MK 11 Diver to PTC | 61* (SD = 11) |
| MK 1 Diver to PTC | 53* (SD = 15) |
| PTC to MK 11 Diver | 60* (SD = 13) |
| PTC to MK 1 Diver | 61* (SD = 13) |
| MK 11 Diver to MCC | 74 (SD = 8) |
| MK 1 Diver to MCC | 49* (SD = 18) |
| MCC to MK 11 Diver | 85 (SD = 6) |
| MCC to MK 1 Diver | 84 (SD = 11) |
| PTC to MCC | 75 (SD = 14) |
| MCC to PTC | 86 (SD = 9) |
| PTC Tender 1 to PTC Tender 2 | 60* (SD = 12) |

*Scores well below the Mil-Std-1472B criteria.

not unlike that just discussed, with the lowest intelligibility occurring between stations at depth and the higher intelligibility when either the talker or listener was topside. Again the open circuit MK 1 and its associated gas flow noise is no doubt contributing to the depressed intelligibility.

As at 450 FSW, adequate data on the MK 14 was not collected at 1000 FSW. Helmet feedback and gas flow interference with the TDCS mike frustrated even the most rudimentary attempts to obtain word list data.

The remaining TDCS communication loops were evaluated at this depth and the results are presented in Table 8. Both Intercom and Command Loops continued to demonstrate performance in the acceptable range. On the Intercom Loop, only OL to PTC communication was of a borderline level. Performance of the Surveillance Loop was similar to that obtained at 450 FSW - below acceptable levels but better undoubtedly than other monitoring loops which do not employ an HSU.

As mentioned earlier, the intelligibility evaluation was continued throughout most of the decompression period on this dive. After an aborted attempt with the MK 14 at 720 FSW, a successful evaluation was obtained at 650 FSW on two MK 11 divers and a MK 1 diver in the water simultaneously. They were tested in the same manner as they were at 1000 FSW. Table 9 shows the results of this evaluation. In all configurations, intelligibility was uniformly higher at 650 FSW than at 1000 FSW. As indicated in Table 9, only four configurations failed to meet at least minimally acceptable levels. Three of these four are highly critical however, since they involve communication between diver and PTC, and between the MK 1 (a potential standby diver) and the MK 11 diver.

TABLE 8

Mean Intelligibility Scores For Intercom, Command, and Surveillance Loops at 1000 FSW.

| Talker/Listener | % Correct |
| --- | --- |
| Intercom Loop | |
| OL to PTC | 70 (SD = 8) |
| MCC to OL | 97 (SD = 3) |
| OL to MCC | 81 (SD = 9) |
| MCC to PTC | 95 (SD = 2) |
| Command Loop | |
| MCC to OL | 91 (SD = 6) |
| MCC to PTC | 94 (SD = 5) |
| Surveillance Loop | |
| PTC to MCC | 64* (SD = 11) |
| OL to MCC | 44* (SD = 10) |

*Scores well below Mil-Std-1472B criteria.

TABLE 9

Mean Intelligibility Scores of Two MK 11 Divers and a MK 1 Diver

In The Water at 650 FSW (Diver Loop)

| Talker/Listener | % Correct |
|---|---|
| MK 11 Diver to MK 11 Diver | 69* (SD = 10) |
| MK 11 Diver to MK 1 Diver | 72 (SD = 10) |
| MK 1 Diver to MK 11 Diver | 66* (SD = 9) |
| MK 11 Diver to PTC | 68* (SD = 9) |
| MK 1 Diver to PTC | 63* (SD = 13) |
| PTC to MK 11 Diver | 71 (SD = 9) |
| PTC to MK 1 Diver | 79 (SD = 7) |
| MK 11 Diver to MCC | 80 (SD = 8) |
| MK 1 Diver to MCC | 71 (SD = 7) |
| MCC to MK 11 Diver | 90 (SD = 9) |
| MCC to MK 1 Diver | 83 (SD = 18) |
| PTC to MCC | 84 (SD = 6) |
| MCC to PTC | 88 (SD = 8) |
| PTC Tender 1 to PTC Tender 2 | 77 (SD = 14) |

*Scores below the Mil-Std-1472B criteria.

Mean intelligibility scores for two MK 11 divers in the water at 560 FSW and 480 FSW are presented in Table 10. At these shallower depths, Diver Loop communications had returned to generally acceptable levels for all configurations. Lower intelligibility continued to be associated with communication between two stations at depth; i.e. diver to diver, and diver to PTC.

At depths of 385 FSW and 190 FSW, the MK 12 SSDS was successfully evaluated. Table 11 shows the results of these two depths. Measured intelligibility was considerably better at 190 FSW than 385 FSW with only one configuration not reaching an acceptable intelligibility level at the shallower depth. MK 12 SSDS suffered many of the same communication difficulties that the MK 14 did, i.e. gas flow noise and helmet feedback problems.

Table 12 shows the mean intelligibility data obtained for a MK 11 diver and a MK 1 diver at 285 FSW. At this relatively shallow depth, all configurations meet or exceed minimally acceptable levels. Even the excessive noise caused by the open-circuit MK 1 was apparently not interfering with satisfactory communications.

Lastly, at 180 FSW, two MK 1 divers in the water were evaluated. The data is presented in Table 13. All communication configurations met or exceeded the recommended intelligibility levels at this depth.

TABLE 10

Mean Intelligibility Scores For Two MK 11 Divers in The Water

At 560 and 480 FSW (Diver Loop)

| Talker/Listener | % Correct 560 FSW | 480 FSW |
|---|---|---|
| MK 11 Diver to MK 11 Diver | 76(SD=15) | 73(SD=9) |
| MK 11 Diver to PTC | 74(SD=10) | 70(SD=11) |
| PTC to MK 11 Diver | 81(SD=11) | 76(SD=7) |
| MCC to MK 11 Diver | 93(SD=4) | 98(SD=2) |
| MK 11 Diver to MCC | 85(SD=10) | 72(SD=7) |
| MCC to PTC | 91(SD=3) | 96(SD=3) |
| PTC to MCC | 84(SD=8) | 82(SD=9) |
| PTC Tender 1 to PTC Tender 2 | 85(SD=7) | 80(SD=8) |

TABLE 11

Mean Intelligibility Scores For Two MK 12 Divers

In The Water at 385 FSW and 190 FSW (Diver Loop).

| Talker/Listener | % Correct 385 FSW | 190 FSW |
|---|---|---|
| MK 12 Diver to MK 12 Diver | 57*(SD=8) | 66*(SD=11) |
| MK 12 Diver to PTC | 60*(SD=9) | 79 (SD=8) |
| PTC to MK 12 Diver | 66*(SD=18) | 78 (SD=13) |
| MCC to MK 12 Diver | 83 (SD=14) | 82 (SD=6) |
| MK 12 Diver to MCC | 70 (SD=9) | 79 (SD=6) |
| MCC to PTC | 89 (SD=6) | 93 (SD=3) |
| PTC to MCC | 77 (SD=9) | 86 (SD=9) |
| PTC Tender 1 to PTC Tender 2 | 72 (SD=16) | 84 (SD=11) |

*Scores well below Mil-Std-1472B criteria.

TABLE 12

Mean Intelligibility Scores of a MK 11 Diver and MK 1 Diver

In The Water at 285 FSW (Diver Loop).

| Talker/Listener | % Correct |
|---|---|
| MK 11 Diver to MK 1 Diver | 78 (SD=7) |
| MK 1 Diver to MK 11 Diver | 74 (SD=7) |
| PTC to MK 11 Diver | 81 (SD=8) |
| PTC to MK 1 Diver | 84 (SD=6) |
| MK 11 Diver to PTC | 81 (SD=7) |
| MK 1 Diver to PTC | 77 (SD=7) |
| MK 11 Diver to MCC | 88 (SD=4) |
| MK 1 Diver to MCC | 83 (SD=7) |
| MCC to MK 11 Diver | 94 (SD=3) |
| MCC to MK 1 Diver | 95 (SD=5) |
| PTC to MCC | 86 (SD=5) |
| MCC to PTC | 93 (SD=4) |
| PTC Tender 1 to PTC Tender 2 | 85 (SD=7) |

TABLE 13

Mean Intelligibility Scores For Two MK 1 Divers

In The Water at 180 FSW (Diver Loop).

| Talker/Listener | % Correct |
|---|---|
| MK 1 Diver to MK 1 Diver | 75 (SD=7) |
| MK 1 Diver to PTC | 80 (SD=8) |
| PTC to MK 1 Diver | 83 (SD=9) |
| MCC to MK 1 Diver | 93 (SD=4) |
| MK 1 Diver to MCC | 80 (SD=7) |
| MCC to PTC | 94 (SD=3) |
| PTC to MCC | 90 (SD=8) |
| PTC Tender 1 to PTC Tender 2 | 89 (SD=9) |

## SECTION 4

## DISCUSSION

In an attempt to summarize the results of the TDCS evaluation, several general findings emerge. TDCS in its present configuration appears to have limitations regarding the (1) depths to which it can be used effectively and (2) the diving rigs with which it will function efficiently.

With respect to the MK 11 UBA, TDCS demonstrated adequate communication to a depth of 560 FSW and borderline communication capability to a depth of 650 FSW when used in conjunction with the MK 1. Below these depths, intelligibility in certain configurations dropped well below minimally acceptable levels.

The INAC component of TDCS designed to eliminate much of the noise associated with open-circuit demand diving systems such as the MK 1, was generally effective in reducing unwanted inhalation sounds, but interacted with the voice component of the signal to produce near-garbled speech at times. This was evident throughout the dive, by the low intelligibility associated with dives in which the MK 1 was dived by itself or in conjunction with other diving rigs.

Use of the TDCS with the MK 14 and MK 12 diving systems was frustrated in large part by helmet feedback difficulties arising from the helmet mounted phones and the exposed TDCS microphone. It may be that the only satisfactory solution to this problem will be a diver-worn skull cap which will bring the phones into direct contact with the head and not feedback as easily through the microphone.

It was also observed throughout the dive, that TDCS is very sensitive to changes in the loudness of the divers' voices. On many occasions, prior to a word list dive, painstaking efforts to set up the volumes correctly at the MCC prior to the actual dive were rendered useless once the diver was in the water and talking softer or louder than the pre-dive period.

Performance of Intercom, Command, and Surveillance loops were generally satisfactory at both 450 and 1000 FSW depths. As in the case of the Diver loop, the Intercom loop's lowest intelligibility occurred when two individuals at depth talked with one another. Although the Surveillance loop had the lowest intelligibility, it should be sufficient for the general chamber monitoring for which it was designed.

The human element in the adjustment of TDCS and its interaction with observed intelligibility cannot be overlooked. The MCC operator must set the volume controls for all stations and, perhaps more importantly, adjust the HSU's various parameters. His settings may or may not coincide exactly with another operators settings at the same depth. He simply listens to the divers voices and makes what he feels are the appropriate adjustments until the voices "sound about right". In the course of this lengthy evaluation, a variety of individuals performed the function of MCC operator. Thus, some of the fluctuation in intelligibility is undoubtedly due to this variable and unrelated to diving rig and depth.

## PART II

## HUMAN ENGINEERING EVALUATION OF THE TDCS

### Introduction

Scope and Procedure:

In addition to the Intelligibility Evaluation of Part 1, an assessment of additional human engineering characteristics was also undertaken. Technicians, who operated the Main Control Console (MCC) were asked to complete questionaires related to their experience with it during the dive. For a sample questionaire refer to Appendix A. In general, the questionaire seeks responses concerning panel layout, headset comfort, human errors, and maintenance characteristics. In addition to the questionaire, a running day-to-day log was kept throughout the dive in which entries were made concerning "critical" incidents, i.e. operator errors or equipment failures. After the dive, the information from the questionaire and log were compiled. This compilation was essentially the data for this evaluation and recommendations concerning future changes to TDCS were made accordingly.

## SECTION 2

### Findings and Recommendations

In general, the TDCS control console affords a remarkably compact size given it's wide range of inputs and outputs (refer to Appendix B), and its solid state electronics and modular design typically provide easy trouble-shooting by technicians when operating problems do arise. These two characteristics should prove highly advantageous in the varied operational settings in which the system will eventually be used.

There were, however, a number of characteristics noted which could be improved. These can be grouped into three areas: console, headphones, and microphones.

Regarding the MCC, the following items were noted. First, MCC operators reported that the different communication loops were easy to confuse when adjusting the system. This sometimes resulted in the adjustment of the wrong loop. It is recommended that a scheme for color-coding the TDCS front panels be devised to reduce confusion and human errors. Second, the momentary cross connect between the Diver loop and the Intercom loop was considered inadequate. It is suggested that it be replaced with a positive position switch. Third, the system does not provide the capability of selective calling from any station except the MCC. It is recommended that the logistics and usefulness of a multi-station select call capability be investigated. Lastly, operators suggested that the INAC control be placed before the input volume control on the Diver loop and be furnished with an indicator light.

With respect to the TDCS headphones, most comments were related to comfort. Several operators reported headaches after a few hours of use and rated TDCS headphone comfort as inferior to the OSF's existing Telex headphones. Headsets themselves and their associated cords were too heavy. Lightweight, comfortable alternatives should be sought. It is also recommended that the headsets at depth have two earphones and not just one, since hearing helium speech and chamber noise with the exposed ear was detrimental to communication. Lastly, it was observed that headphone connecting plugs experienced a relatively high failure rate and a redesign or alternative design may be required.

Regarding TDCS microphones, several observations were recorded. First, mike position relative to the mouth was highly critical if adequate communication was to occur. This was particularly evident in diving helmets not requiring an oral/nasal, i.e. MK 12 and MK 14. It was also obvious that moisture or water on the microphone had great affects on speech clarity. In the diving environment, system immunity to the effects of moisture is essential. Lastly, mike connectors and whips were subject to relatively high failure rates suggesting the need for a closer examination of their construction or design characteristics. Only one loop interaction problem was observed on the dive. When the Command loop was used, it fed back through the Surveillance loop and was unscrambled, causing a distracting noise at the MCC.

After implementation of the above mentioned recommendations and given that additional changes may be necessary after operational use, the TDCS should be basically sound from a human engineering standpoint.

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# APPENDIX A

# HUMAN ENGINEERING QUESTIONNAIRE

TDCS

HUMAN ENGINEERING QUESTIONNAIRE

Instructions: Please circle the most appropriate answer and make additional comments where necessary. If you have gripes about TDCS, now is the time to tell us.

1. How would you rate the intelligibility of TDCS as compared to the OSF's standard communication system?

   MUCH BETTER    SLIGHTLY BETTER    SLIGHTLY WORSE    MUCH WORSE

2. How would you rate the comfort of the TDCS headphones as compared to the OSF's telex system?

   MUCH BETTER    SLIGHTLY BETTER    SLIGHTLY WORSE    MUCH WORSE

   What other comments about the TDCS headphones:___________________________

3. What difficulties, if any, did you encounter when operating the TDCS Main Control Console?___________________________

4. What changes would you make in the layout of the TDCS Consoles? Did you find the panel easily understandable?___________________________

5. Did you ever reach for or turn the wrong knob? If so, which one?

6. What do you like most about TDCS?___________________________

7. What do you like least about TDCS?___________________________

8. If you could change one thing about the TDCS, what would it be?

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TO BE COMPLETED BY COMMUNICATIONS TECHNICIANS.

9. Which "parts" of the TDCS demanded the most attention during the dive?

10. What suggestions do you have for improving the maintenance aspects of TDCS?

11. During adjustments to the MCC to improve or change communications, which knobs were most frequently used? Were you satisfied with their location?

# APPENDIX B

## MCC FRONT PANEL PHOTOGRAPHS

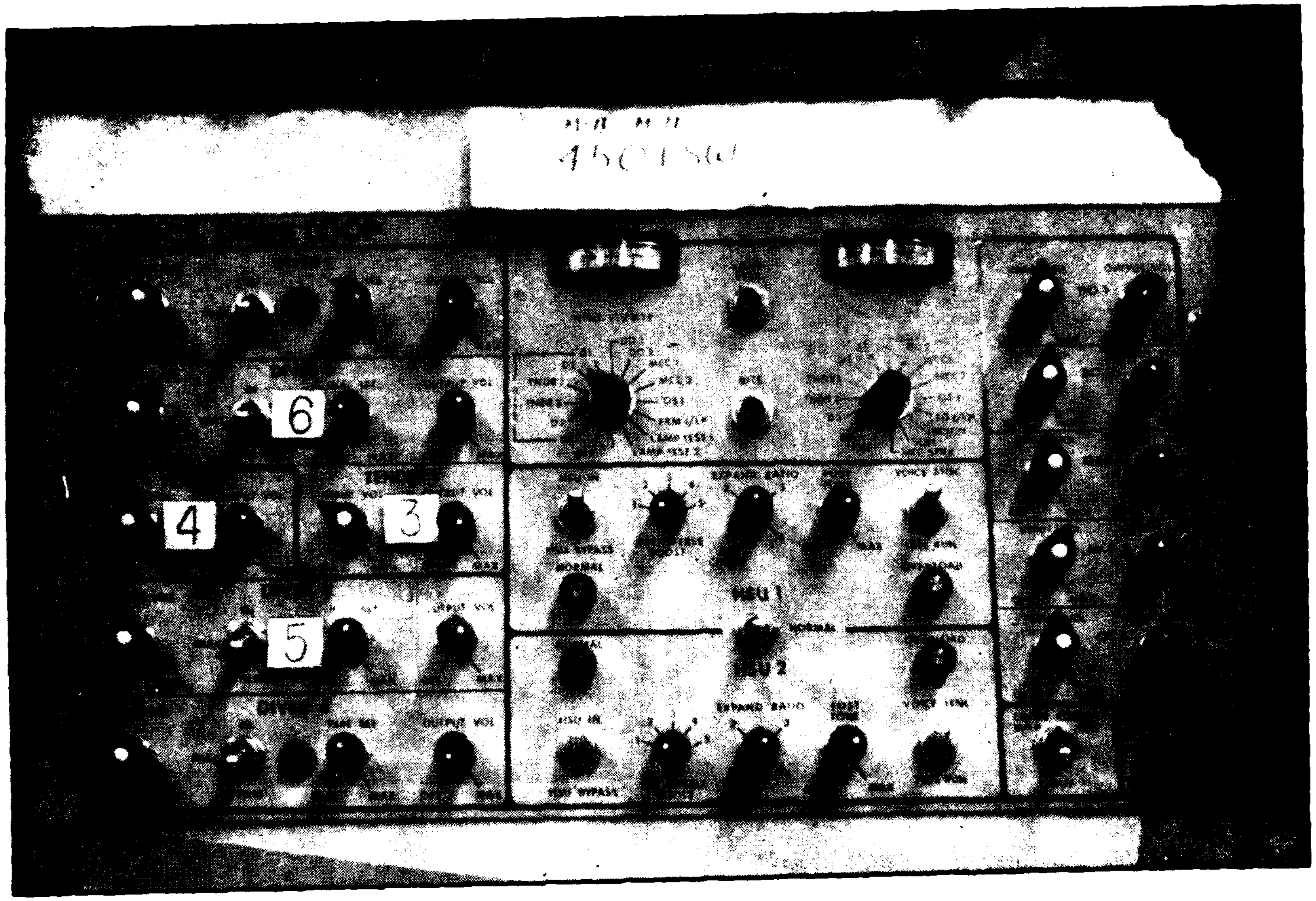


FIGURE B1. M 11 - M11 450 FSW